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TECHNOLOGICAL APPROACH FOR PRODUCTION OF SILICATE INSULATING MATERIALS AND PANELS FOR THE DECORATIVE CLADDING OF BUILDINGS

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ABSTRACT

A conceptual model of an industrial unit for experimental application in a production environment of a technology approach developed in laboratory conditions for the production of various silicate composite materials has been developed. The separate production sections specialized for the implementation of different stages of the technological process and the necessary standard and innovative technical equipment are considered. The specific characteristics of the various products and the existing potential opportunities for their application in different areas of construction are analyzed. The presented technological methodology allows efficient utilization of waste silicate raw materials and cost-effective production of various thermal insulation materials and colored decorative panels for cladding buildings.

Keywords: waste raw materials, silicate materials, conceptual model.

INTRODUCTION

Glassy materials are characterized by an amorphous structure, specific physicochemical and mechanical properties and are of significant production and research interest. A number of author groups study the structure of the vitreous state and the processes of glass formation in different experimental compositions [1 - 14]. At the same time, a variety of standard and innovative glass materials are widely used in the manufacture of various products: window glass, automotive glass, optics materials, electric glass displays, household utensils, medical devices, glass packaging for food products, pharmaceutical glass packaging, colored art glass and many other. Due to the active daily operation of various glass products, the existing quantities of waste glass materials inevitably increase. At this type of waste products, the various types of standard glass packaging intended for storage of products with a limited shelf life have a significant share. Therefore, the development of cost-effective and environmentally friendly technological solutions for waste glass recycling and production of competitive durable products is relevant.

The idea for an experimental site, including a technological line for the production of granules of foam glass and composite materials on this basis is very annual and is based on research experience, with the participation and implementation of several projects funded by BSMEPA (The Bulgarian Small and Medium Enterprises Promotion Agency) at the Ministry of Economy and Research Fund to the Ministry of Education [15 - 18]. In the implementation of some applied research projects, various original innovative equipment has been developed, potentially applicable in real production conditions [19 - 22].

Various foam glass products (granules, aggregates, panels) are used for insulation of buildings and facilities or in the role of bulk materials. Granulated foam glass and the materials obtained with its participation surpass a number of classic thermal insulation products in terms of most of its performance characteristics [23, 24], resistance to weathering and cyclical climate change [25 - 27]. The application of thermal insulation products derived from foam glass materials allows the construction of effective and long-lasting thermal insulation systems with high operational resistance. At the same time, thermal insulation composites based on granular foam glass and inorganic binders have been developed [28, 29].

The main aim of the present work is to represent in principle the possibilities for experimental application in production conditions of technological methodology for the production of various silicate thermal insulation composite products and colored decorative panels for building cladding. At the same time, the realization of the presented conceptual design allows the testing of developed innovative equipment and determination of their operational characteristics: productivity, operability, durability, maintainability and many others.

RESULTS AND DISCUSION

Basic requirements

The presented experimental industrial unit specializes in the production of foam glass products and is provided with specialized facilities and equipment developed and manufactured according to inventions for the construction of a technological line for the obtaining of bulk foam granules, foam gravel and various elements of composite material. The proposed plan scheme (Fig. 1) is designed for an ideal site, but can be adapted for any available site in existing production facilities of similar size.

The production areas are approximate, overlapping and located in an industrial unit 20x30 m with a shed 20x10 m. They can be located in another way depending on the free specific area during project implementation (Table 1).

The main equipment needed for the preparation of the raw materials and the production of granulated foam glass are presented in Table 2. The construction of the devices is safe, does not emit toxic gaseous products and carcinogenic substances. The transport and storage of the powdered glassy raw material obtained after grinding is carried out in closed facilities (mainly closed bunkers). If possible, an aspiration dedust system can be provided. Principle schemes and descriptions of the proposed experimental industrial unit (Fig. 1), the technological processes concerning the manufacture of raw (Fig. 2) and foamed granules and the individual stages of the whole production approach (Fig. 3) are presented.

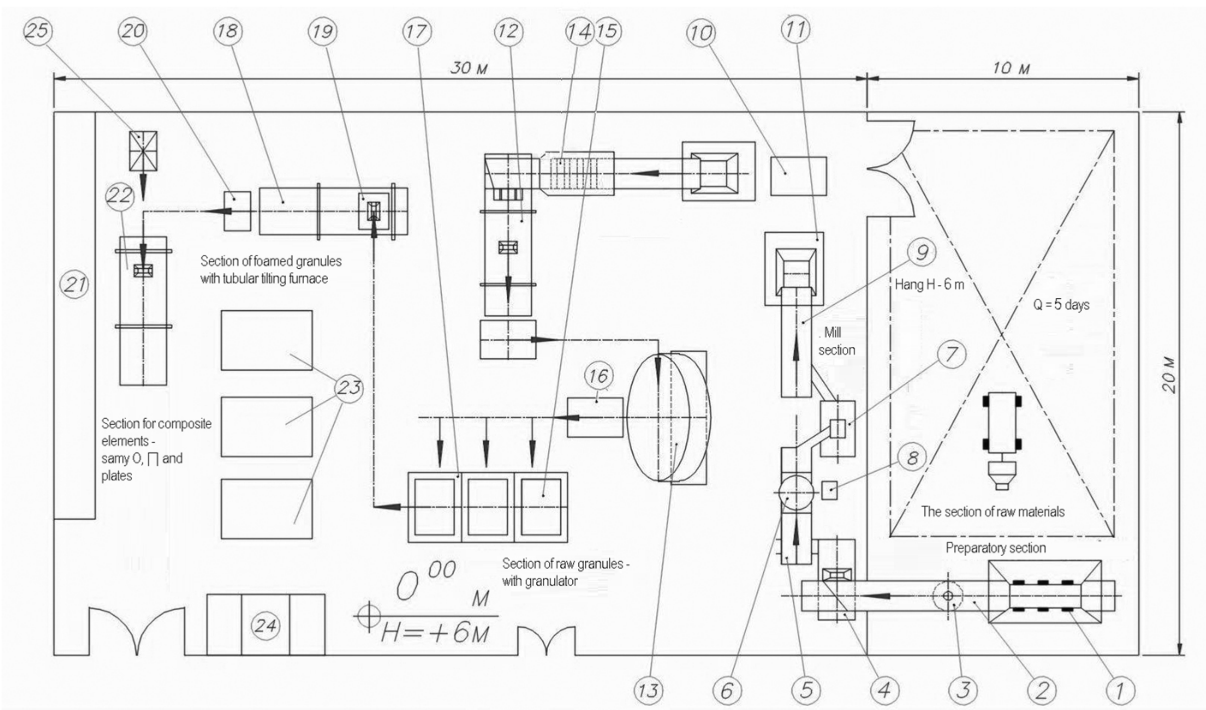

Fig. 1. Exemplary arrangement of the equipment of the technological process for production of raw and foamed granules and composite products with foam granules.

Table. 1. List of required main areas and units in the experimental industrial unit.

Dimensions	A	B	H	Level
Type of room	m	m	m	-
1. Storage of raw materials	20	10	6	Shed
2. Preparatory section	20	5	6	I floor
3. Mill section	15	10	6	I floor
4. Section of raw granules - with granulator	20	5		I floor
5. Section of foamed granules with tubular rotary furnace	10	5	6	I floor
6. Section for composite elements	20	10	6	I floor

Table. 2. Preliminary title list of necessary machines and equipment.

Number	Machines and equipment
	Storage of raw materials
1	Feed hopper
2	Conveyor belt
	Preparatory section
3	Shower for washing glass waste
	Mill section
4	Crusher type Vibromax VM - 20 vibrating
5	Conveyor belt
6	Electromagnetic separator
7	Sieve vibrating flat closed
8	Non-glass waste hopper
9	Conveyor belt for carrying
10	Cart for supplements with scales
11	Vibrating mill
12	Ball mill - homogenizer
	Section raw granules
13	Granulator
14	Buckets or scrapers conveyor
15	Trays for drying raw granules
16	Cart with trays for ready raw granules
17	Dryer raw granules
	Section of foamed granules
18	Rotary furnace for granules
19	Hopper with sieve for feeding raw granules
20	Hopper for foamed granules
	Section for composite elements
21	Shelves for drying and hardening
22	Mixture homogenizer
23	Leveling table for making products
24	Matrices for products
25	Hopper for foamed granules

Production sections specialized in the implementation of various stages of the technological process

Raw storage area and mill section

The raw material - wastes arrives by truck and stored outdoors in a prepared storage space, separated under a canopy near an existing or new room.

From the receiving hopper through a series of conveyors and crushing machines the raw material (glass household waste) is transported to a vibration mill for coarse grinding. After coarse grinding, the raw material is inserted into a ball mill for final grinding and homogenization of the resulting mixture. The foaming additives (glycerol, calcium carbonate or other), modifiers and colorants (if necessary), according to the developed approaches, are introduced towards the end of the grinding process. The ball mill also acts as a mixing reactor and homogenizer in order to manufacture the raw granules.

Granulating compartment and section for raw granules

The next process is granulation with a granulator. The use of a granulator is a more efficient method of production than pelleting, which requires the application of matrices and automated or classic hydraulic presses. In mass production of granules, pressing as a process increases the cost and complicates the technological cycle of production.

The preparation of the raw material mixture is a main stage in the overall technological process in the production of granules and is performed in 2 stages. The first stage - microgranulation (Fig. 2), can be considered as an agglomeration method in which the powdered glass material (fraction < 100 μm) is compacted without changing of the chemical composition. With

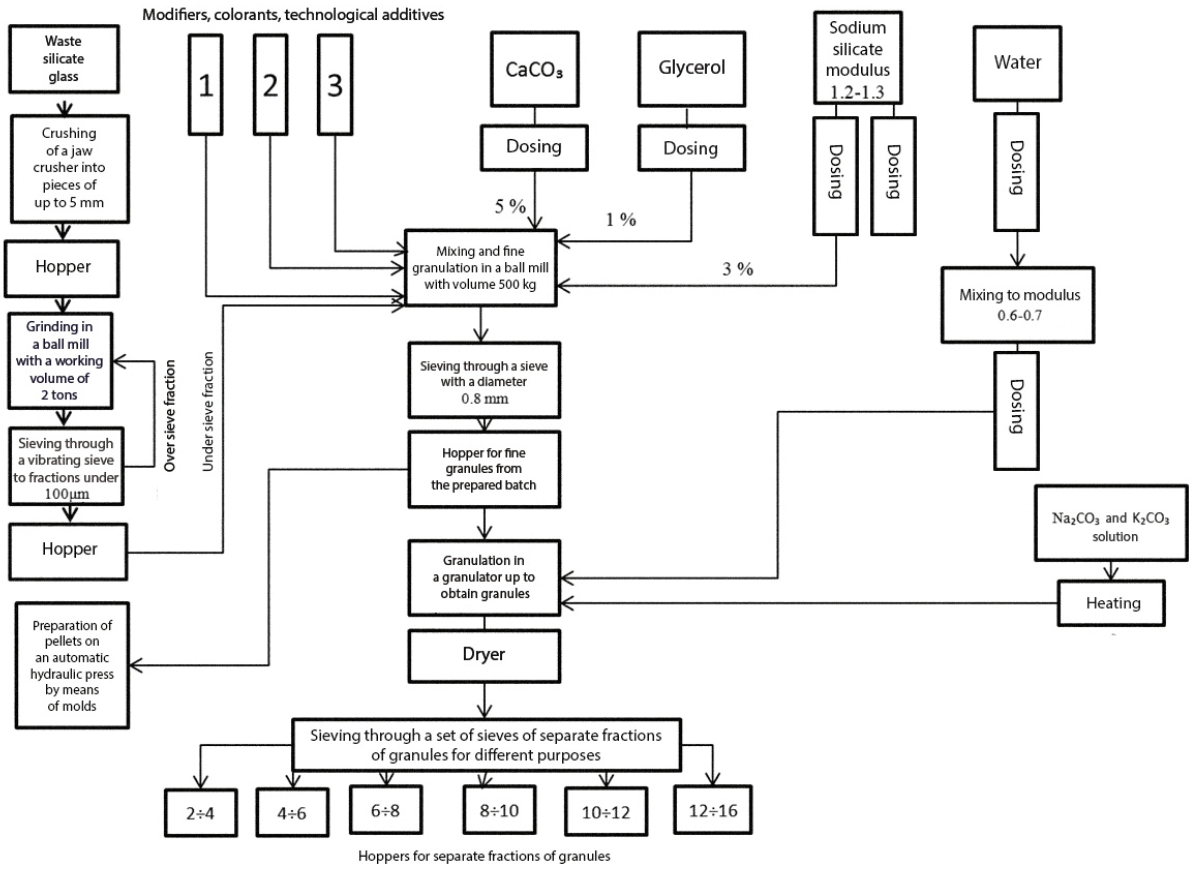

Fig. 2. Technological scheme of preparation of raw materials for operation of a device for obtaining granules from foam glass.

the obtained relatively compact mass, there is no risk of stratification and dusting in its further use for the production of foam granules. The uniform distribution of the individual charge components achieves a homogeneous composition of the microgranules with maximum dimensions from 0.1 - 0.2 to 0.8 mm.

As a technological additive in the role of plasticizers to the charges are introduced 1 % glycerin and 3 % sodium silicate with silicate modulus 1.2 - 1.3 in the first stage of granulation and with silicate modulus 0.6 - 0.7 in the second stage of granulation.

In the second stage of granulation, the glassy raw material (already in the form of micro granules) and the required amounts of foaming agents, modifiers and colorants (if necessary) are treated in a ball mill after dosing. After partial grinding of the coarse microgranules and homogenization, the material is placed in the granulator. The second stage of the granulation process is additional compaction and aggregation of the product to form raw granules of different and much larger sizes, depending on the specific purposes of application of the final product. The sizes of the raw granules during the re-granulation vary from 2 to 16 mm.

At this technological stage it is planned the investigation of the conditions and possibilities for obtaining (from the developed compositions) of silicate foam granules with increased strength indicators and different color characteristics applicable to the production of composite products, which could be considered as an alternative to some standard materials with traditional use in construction.

Furnace section and section for foamed granules

The raw granules are fed into the hopper above the furnace and are foamed independently in the rotating inclined part of the furnace tube, passing through several separate temperature zones in it. At the end of the technological process, the granules are removed

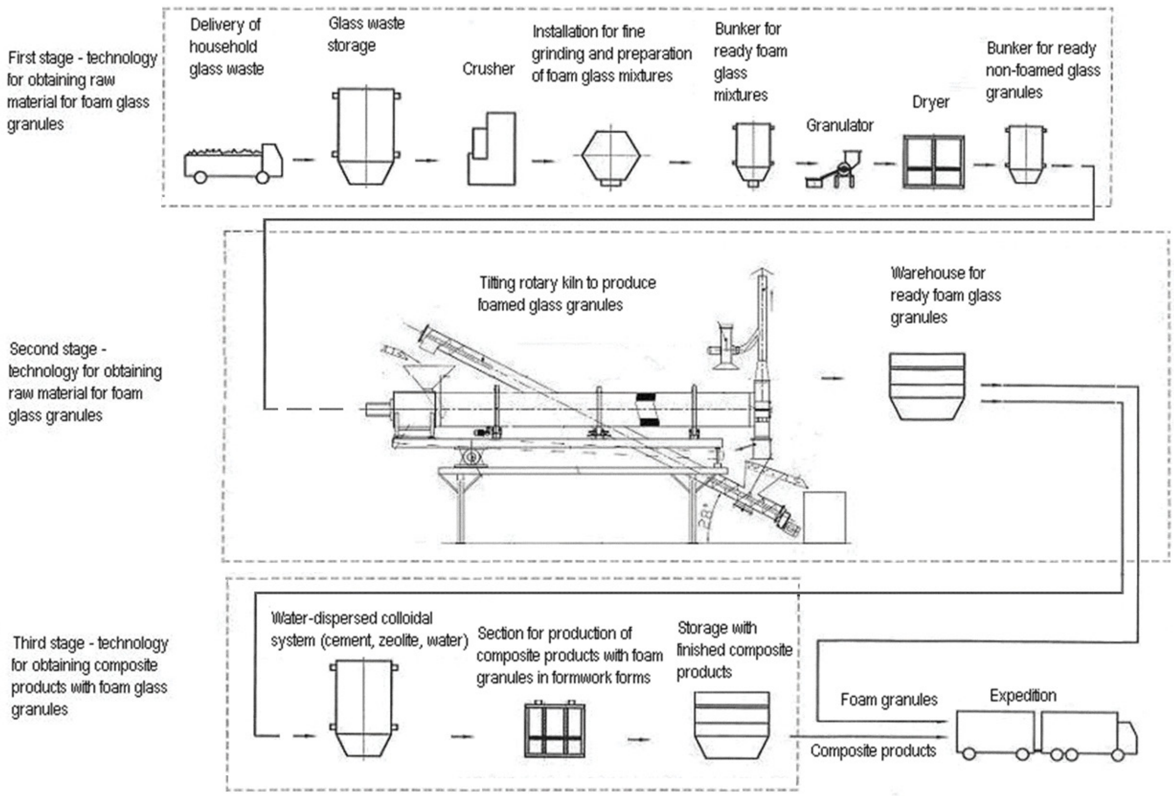

Fig. 3. Sequence of the technological process for obtaining raw and foamed granules and composite products with foam granules.

from the rotating tube in a foamed state. The granules are mixed with special filler, acting as both a heat carrier and a separator of the granules, preventing them from agglomeration during foaming. The inclination of the tubular part of the furnace determines the different stay of the granules in the technological zones for foaming, tempering and cooling is regulated and also determinate the diameter of granules. With smaller diameters, the slope is larger. The thermal treatment of the granules is carried out in several stages by applying specially developed modes (compliant with to the specifics of the compositions and the and the required performance indicators of the final products) with maximum temperature values in the range from 740°C to 930°C. At this technological stage it is envisaged to obtain different fractions of foamed glass granules (with dimensions of 4 - 30 mm, 20 - 30 mm and of 40 - 70 mm) with various functional purposes. At the same time, the experimental study of the operating characteristics of the furnace allows the determination of the optimal quantities and size of the filler and the slope of the facility depending on the diameter and the amount of raw granules introduced.

Compartment for production of composite elements

It is planned to produce of different types of composite products – semi-O-shaped, Π-shaped and flat elements, panels and other products from different fractions of granules (with different diameters), hydraulic binders and other components. With the implementation of the new experimental technological line in this section under real production conditions will be applied and further improved the developed (in laboratory conditions) technology for obtaining composite materials and various products - non-flammable, waterproof, durable, sound- and thermal insulating building elements. The composite material is applicable for the production of panels for wall and ceiling cladding, construction of internal partition walls, thermal insulation flooring and production of thermal insulation concrete storage of heating energy in residential and industrial buildings and favours environmental protection due to reduced energy consumption for heating. A possible approach for installation of composite panels on external facade walls is the standard method widely used in practice, including: installation of insulation boards by standard adhesive composition, doweling, deposition of polymer-cement coating together with reinforcing mesh and application of a finish coating resistant to the climatic impact of the environment. The main goal in building with adequate thermal insulation system is to optimize the thickness of the insulating layer to the extent of obtaining a „Passive Wall" - a wall with minimal loss of heat flow. The material is suitable for insulation protection of communication systems in residential, public and industrial sites and installations for electricity, water and gas supply after renovation of buildings. Another promising opportunity for the use of various composite panels and profiles is the insulation of production facilities: tanks, stationary tanks, reaction vessels, distillers, pipelines and others. The production of foam glass granules with different color characteristics allows the manufacture (in combination with standard or specially colored hydraulic binders) of decorative panels and mosaics, applicable for interior and exterior cladding of buildings and other architectural objects.

To obtain the planned products, suitable perforated formwork matrices have been developed and the provision of auxiliary equipment and the necessary consumables is envisaged. Under specific production conditions, the optimal parameters of the individual technological processes required for the manufacture of composite products will be experimentally determined.

The quantities of the separate components in the compositions vary widely and are consistent with the final performance characteristics (strength, density, thermal conductivity, sound insulation properties, etc.) of composite products and their cost. Other factors determining the prescription compositions are the various aspects of the production process: manufacturability in the preparation of samples, productivity for a certain reporting period, the presence of waste, the possibility of cost-effective recycling of defective products, safe working conditions, production of environmentally friendly products, etc. As starting compositions, it is appropriate to initially adopt the compositions used in the preparation of experimental samples and prototypes in the laboratory. The establishment of the optimal compositions (for the different types of products) is envisaged to be carried out by conducting a series of experiments under semi-industrial conditions and preparing pilot batches of products. The predominant components in the compositions used are inorganic hydraulic binders (Portland cement CEM I 42.5 N, CEM I 52.5 N, CEM I 52.5 R, etc.), different fractions of foam glass granules and water. The presence of limited amounts of activated zeolite (clinoptilolite, fraction below 63 μm) in the compositions has a beneficial effect on some of the performance characteristics (physico-chemical and mechanical properties and others) of the final products. The introduction of a suitable air-entraining admixture in the composition reduces the weight of the samples, but at the same time reduces the strength characteristics, therefore its use must be in accordance with the forthcoming application of the product. If necessary, it is possible to introduce reinforcing fibers (basalt, steel, etc.), water-reducing additives, river sand, various inorganic fillers and other materials to the compositions. On the other hand, the introduction of pigments and appropriate technological additives to white Portland cement and its application together with different fractions of colored foam glass granules for production of decorative cladding panels provides an opportunity to obtain a wide range of diverse aesthetic and functional products.

For the production of composite blanks and products, a simplified methodology has been developed, applicable in the presence of available materials, without the participation of highly qualified personnel. The preparation of various composite products is carried out through several successive technological stages. The required quantities of different fractions of ordinary or colored foam glass granules, cement, technological additives and water are weighed. Preparation of also an aqueous dispersed colloidal system containing hydraulic inorganic binder (Portland cement), activated zeolite, water and technological additives. With constant stirring, introduction to the homogenized system of different fractions of foam granules until complete wetting of their contact surface. The production of composite products with different functional purpose is carried out in a specialized section, equipped with a set of formwork matrices, vibrating stands and auxiliary equipment. The molding of the samples is realized by placing the resulting mixture (cement solution-granules) in the pre-prepared formwork forms with a perforated bottom, which allows the separation of the excess liquid phase, which reduces the mass of the final samples. The application of vibration treatment for 50 min (or longer period), by placing the formwork forms on vibrating stands, provides optimal volume distribution of the various fractions of foam granules, faster and more efficient removal of excess liquid phase, which reduces the mass of the samples. The bulk density of the composite material increases with the increase of the amount of introduced smaller fractions of foam glass granules in the initial mixture and the applied time of vibration treatment. The formwork forms containing the prepared mixtures are stored in a specialized room and after a stay of up to 72 hours the obtained batch of samples is carefully stripped by disassembling the used matrices. The released formwork forms are cleaned, assembled and re-introduced into the production process, and the technological cycle is repeated. Based on the considered methodology, two different technological approaches are applicable for preparation of products from the obtained mixture (granular-cement solution): molding in the formwork matrixs of products with final dimensions, technological stay, stripping and retouching of the obtained final samples or initial molding of composite semi-finished products (boards and others), technological stay, release of the blanks, additional technological stay (necessary to increase the strength of the samples), cutting and final processing to the required final dimensions. The application of the outer surfaces of the composite products the suitable coatings and screeds with different properties, in accordance with the specific conditions of application, increases the efficiency of the product. The finished products obtained are stored in warehouses and, if necessary, shipped to the commercial network or to specific consumers.

In the preliminary studies of various experimental composite samples, approximate values of the coefficient of thermal conductivity (λ) in the range from 0.047 to around 0.24 W/m K were determined.

The technological approach used for the production of composite samples provides some main advantages: recycling of silicate waste products, use of accessible materials with relatively low cost (Portland cement, etc.), use of simple technological processes in the preparation of semi-finished products and final products, technological activities feasible by low-skilled personnel, possibility for application of available equipment in the implementation of part of the technological process, obtaining non-flammable, waterproof, environmentally friendly, products with long service life, comparable to the service life of architectural sites.

The exploitation characteristics of the composite products prepared according to the developed methodology is determined by a number of factors: bulk density of the prepared foam glass granules, used Portland cement, specifics of technological additives, characteristics of the cement mortar, used foam granule fractions, thixotropic properties of the resulting mixture. construction of the formwork matrices, duration of the vibration treatment, volume distribution of the different fractions of foam granules, removal of excess binder, duration of the technological stay, temperature and humidity in the working premises, presence of air cavities in the material volume, application of functional surface coatings, technological methods for finishing of the prepared blanks, final dimensions of the finished products, conditions of storage and transport of the products and others.

CONCLUSIONS

The conceptual design of an experimental industrial unit for the manufacture of foam glass granules and products is the basis for discussion, adjustments and development of a working design for the production of granular foam glass, pieces and various elements of composite materials based on foam glass granules.

The developed technological approach is applicable for the production of various composite products (O-pipe elements, Π-shaped elements and plates), sound and thermal insulation panels for wall and ceiling cladding or for the construction of internal distribution and partition walls. The manufacture of different colored foam glass granules allows the production (in combination with standard or colored Portland cement) of aesthetic silicate panels, applicable for decorative cladding of buildings. Another promising aspect of the application of different fractions of foam glass granules is the production of thermal insulation flooring and thermal insulation concrete. The presented methodology is suitable for the preparation of various monolithic products for direct use or composite blanks, subject to additional technological processing.

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